Upgrade of Level 1 Muon Trigger Logic for the v13 Trigger List

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Abstract

This note describes the logic used to form Level 1 Muon trigger, and describes changes between previous versions of the logic and the version currently in use for the v13 trigger list. The version currently in use was loaded on June 29, 2004, starting with run number 194621.

1 Introduction

The Level 1 Muon Trigger system receives inputs from the central scintillators (Aϕ, Bϕ, and CMSC counters), the forward pixels (A-, B-, and C-layer pixels), the central wire chambers (PDTs), the forward wire chambers (MDTs), and the central track trigger (CTT). For the purpose of this document, "scintillator" triggers will be defined as triggers based on either central scintillators or forward pixel hits, "wire" triggers will be defined as triggers based on PDT or MDT hits, and "CTT" triggers will be defined as triggers based on tracks from the central tracker.

Level 1 Muon triggers are formed at three different levels: octant, regional, and global. Octant-level triggers are formed based on hits in a single octant. Regional triggers are formed based on the octant-level triggers within a region. Independent regional triggers are formed for the central, north, and south regions. The global trigger, in turn, forms triggers based on the regional trigger decisions. It is these global trigger terms that are passed on to the trigger framework.

2 Octant-Level Triggers

2.1 Scintillator Triggers

Scintillator triggers are generated from hits in the Aϕ, Bϕ, or CMSC counters in the central region of the detector and hits from the A-, B-, or C-layer pixels in the forward region of the detector. In the central Bϕ and CMSC counters, where there are two phototubes per counter, both phototubes must fire in order to register as a hit at Level 1.

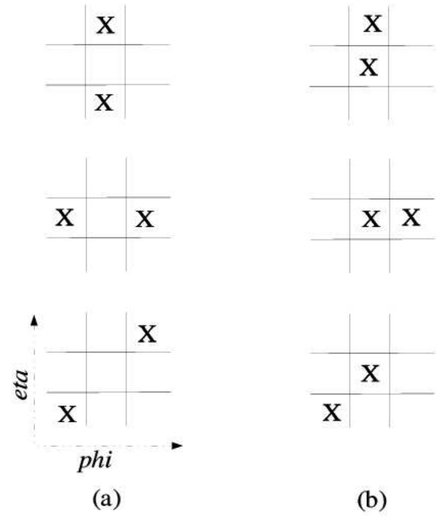

Figure 1: Scintillator hit patterns that (a) fire and (b) do not fire the dimuon trigger. A hit in a counter is marked by an ’X’. All hit patterns shown will fire the global single muon trigger.

2.1.1 Loose Trigger

In the forward region, a loose single muon scintillator trigger is defined as a hit in an A-layer pixel. A forward “wide” trigger is defined as a loose single muon scintillator trigger in the region $|\eta| < 1.6$ (that is, a hit within the η-coverage of the CFT). In octants 0-4 and octant 7 of the central region, a loose scintillator trigger is defined as a hit in an Aϕ counter. In octants 5 and 6 of the central region, there is incomplete Aϕ coverage because of detector supports. In those octants, the loose single muon scintillator trigger is defined as a hit in either an Aϕ, Bϕ, or CMSC counter.

The loose dimuon scintillator trigger is defined as two scintillator hits in non-adjacent scintillators. Hits in two “diagonally adjacent” scintillators (that is, two scintillators separated by one unit in ϕ and one unit in η) will not fire the dimuon trigger. Diagrams of hit patterns which will and will not fire the dimuon trigger are shown in Figures 1a and 1b, respectively.

In all sections of the detector except central octants 5 and 6, the hits are counted in the A layer only. In central octants 5 and 6, however, the dimuon trigger will fire if there are two hits in the Aϕ, two hits in the Bϕ, or two hits in the CMSC. Hits are not added across layers, however, so one Aϕ hit and one CMSC hit will not cause the dimuon trigger to fire.

2.1.2 Tight Trigger

A tight scintillator trigger in the forward region is defined as a coincidence between A- and B-layer pixels. Additionally, the B-layer pixel hit must fall within a certain angular distance (or "road") of the A-layer hit. The η-ϕ separation between the A-layer hit and the B-layer hit can be no greater than 1 counter in ϕ and 1 counter in η. That is, if there is an A-layer hit in an A-layer counter at η=X, ϕ=Y, there must also be a hit in either the B-layer counter at η=X, phi=Y or one of its adjacent counters in order for the tight scintillator trigger to fire.

A tight scintillator trigger in the central region requires a coincidence either of Aϕ and CMSC counters or of Aϕ and Bϕ counters. (In octants in which there are no Bϕ counters, the coincidence is obviously only between Aϕ and CMSC counters.) Because the Aϕ, Bϕ, and CMSC counters have differing segmentation in ϕ and η, the scheme for designating a tight scintillator road is more complicated than the scheme used in the forward region. The central roads were formed by studying the scintillator hit patterns of a sample of 4-GeV Monte Carlo muons, and creating η- and ϕ- boundaries for each Aϕ counter. To form a tight road, a Bϕ or CMSC hit must fall within both the η range and the ϕ range of the Aϕ counter registering a hit. A plot of these ranges for the CMSC counters is shown in Figure 2.

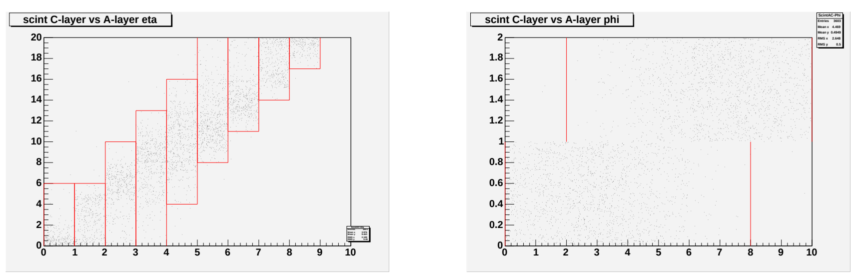

Figure 2: Range of CMSC counters that will cause a tight scintillator counter to fire vs. Aϕ hits in (a) η and (b) ϕ for a Monte Carlo sample of 4 GeV muons. The red lines indicate the size of the roads.

In octants 5 and 6 of the central region, the tight scintillator trigger will also fire if there is a hit in a B-hole counter and at least one C-hole counter. There is no eta/phi separation cutoff for this component to the trigger; a hit in either B-hole counter in the octant along with a hit in any C-hole counter in that octant will fire the tight trigger.

Because the tight scintillator trigger generally requires an A-layer scintillator hit (with the exception of the triggers using the bottom hole counters), the tight dimuon trigger is anchored in the A-layer. When multiple tight roads are found, the position of the A-layer scintillator hit in each road is compared. If there are at least two A-layer hits in non-adjacent scintillators, the tight dimuon trigger fires. In central octants 5 and 6, the dimuon trigger will fire if there are at least two tight triggers anchored in non-adjacent Aϕ counters, or if there is a tight trigger anchored in Aϕ along with a tight trigger anchored in a B-hole counter.

2.2 Wire Triggers

Wire triggers are based on hits in the drift chambers of the muon system. For a chamber with N decks, the wire trigger requires hits in at least (N-1) of the decks. Additionally, these hits must be confined to a small range in η. The size of this range varies with the η-coordinate of the hit in the lowest deck, but is generally about 3-5 cells wide. Hits meeting these conditions form a "stub" or "centroid". This centroid, when confirmed by a scintillator hit, causes the Level 1 wire trigger to fire. The confirming scintillator hit generally must occur in the same layer as the centroid hit, although there are exceptions in cases in which the scintillator and wire coverage do not coincide.

2.2.1 Loose Trigger

In the forward region, a loose single muon wire trigger is defined as an A-layer centroid confirmed by an A-layer pixel hit. Similar to the scintillator trigger, a forward "wide" wire trigger fires if the A-layer pixel hit is within the region $|\eta|$¡1.6. In octants 0-4 and octant 7 of the central region, a loose wire trigger is likewise defined as an A-layer centroid confirmed with an Aϕ hit. Because the PDTs do not provide phi discrimination, a single centroid may be confirmed by multiple Aϕ hits. A plot showing which Aϕ scintillator may confirm a given centroid is given in Figure 3.

The loose dimuon wire trigger is formed by counting scintillator hits that have confirmed wire centroids. The counting scheme is generally the same as for the loose dimuon scintillator trigger, with the only difference occurring in central octants 5 and 6. Because there are no B-layer PDTs directly below the B-hole counters, the B-hole counters are not used in forming the loose wire triggers.

2.2.2 Tight Trigger

In the forward region, a tight wire single muon trigger is defined as an A-layer centroid confirmed by an A-layer pixel hit and a B-layer centroid confirmed by a B-layer pixel hit. The requirements for the eta-phi separation of the A-layer and B-layer pixel are the same as for the tight scintillator trigger.

A tight wire single muon trigger in the central region consists of either (a) an A-layer centroid confirmed by an Aϕ hit and a C-layer centroid confirmed by a CMSC hit, or (b) an A-layer centroid confirmed by an Aϕ hit and a B-layer centroid confirmed by either an A-layer or B-layer scintillator. Because there is only limited Bϕ coverage of the central region, some B-layer centroids are confirmed with Aϕ scintillators, meaning that it is possible for the tight wire trigger to fire with only one layer of scintillator hits (see Figure 4). This contrasts with the forward region, where there must be hits in both the A- and B-layer pixels for the tight wire trigger to fire. Thus, while the forward tight wire trigger can fire only if the forward tight scintillator trigger fires, it is possible (via the central AB wire roads) for the central tight wire trigger to fire without the central tight scintillator trigger firing.

Finally, central octants 5 and 6 once again provide an additional complication to the trigger. The tight wire trigger in these octants is defined as either (a) an A-layer centroid confirmed by an Aϕ counter and a B-layer centroid confirmed by a Bϕ counter, (b) an

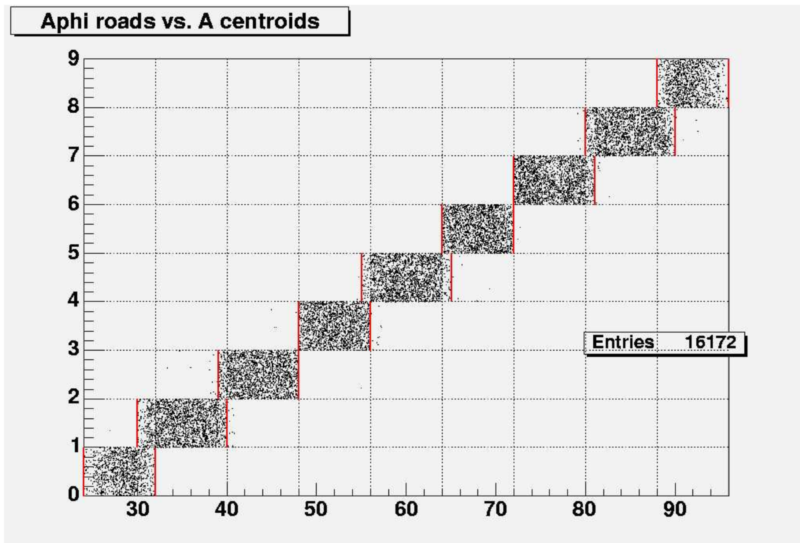

Figure 3: Aϕ roads versus A-layer PDT centroid number, for a Monte Carlo sample of 4-GeV muons. (Central octants 5 and 6 have been excluded from this plot.) The vertical axis represents the relative η position of the Aϕ counter, and the horizontal axis represents the centroid value of the PDT. The red lines show the range of centroids allowed in each eta road in the Level 1 Muon trigger.

A-layer centroid confirmed by an Aϕ counter and a C-layer centroid confirmed by a CMSC counter, or (c) a B-hole counter and a C-hole centroid confirmed by a C-hole counter. Because there is no B-layer PDT for the B-hole counter to confirm, the 'BC' road for this trigger requires only one centroid.

2.3 CTT Triggers

Level 1 Muon triggers involving the CTT match CTT tracks with hits in the muon scintillator and wire systems. The CTT tracks are sent for four different transverse momentum thresholds (roughly 1.5 GeV, 3 GeV, 5 GeV, and 10 GeV), which are referred to as 'PT1','PT2','PT3', and 'PT4' by the Level 1 Muon system. The trigger integrates over the transverse momentum thresholds to form an inclusive trigger, so that any time a trigger based on a PT4 track fires, the corresponding triggers for PT3, PT2, and PT1 tracks will also fire.

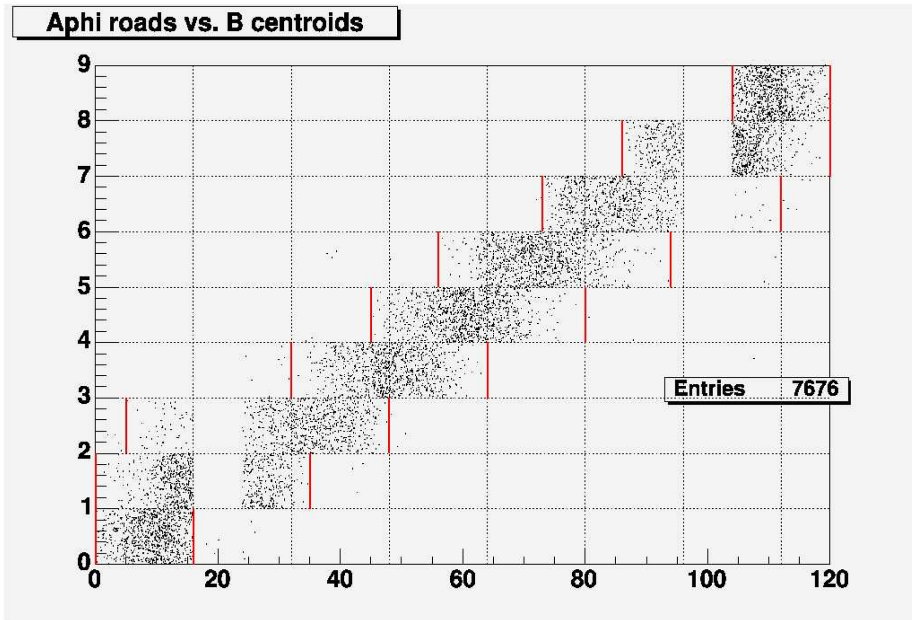

Figure 4: Aϕ roads versus B-layer PDT centroid number, for a Monte Carlo sample of 4-GeV muons. (Central octants 5 and 6 have been excluded from this plot.) In the sections of the central detector where there are no Bϕ counters, B-layer centroids are confirmed by Aϕ counters. The red lines show the range of centroids confirmed by each eta road in the Level 1 Muon trigger.

2.3.1 Loose Trigger

A loose CTT+scintillator trigger is fired if a CTT track is received, a loose scintillator trigger is fired, and the ϕ coordinate of that scintillator matches the ϕ coordinate of the track. A loose CTT+wire trigger is fired if a CTT+scintillator trigger is fired and a loose wire trigger is fired. Because the CTT+scintillator trigger is formed on a different trigger card than the wire trigger, it is possible that the scintillator that confirms the CTT track is not the same as the scintillator that confirms the wire hits. However, both scintillator hits must occur in the same region and octant of the detector.

2.3.2 Tight Trigger

A tight CTT+scintillator trigger is fired if a CTT track is received, a tight scintillator trigger is fired, and the ϕ coordinate of the A-layer scintillator hit from the tight scintillator trigger matches the ϕ coordinate of the track. This is a slight change from previous versions of the trigger, in which the CTT track was matched in ϕ to a B-layer pixel hit in the forward region, and in which the CTT+scintillator trigger would fire if that B-layer pixel hit matched a CTT track and either an A-layer or C-layer pixel hit. The change was brought about to bring the scintillator requirements for this tight trigger into agreement with the scintillator requirements for the scintillator-only tight trigger. A tight CTT+wire trigger is fired if a tight CTT+scintillator trigger and a tight wire trigger are fired. As with the loose CTT+wire trigger, it is possible that the A-layer scintillator hit that confirms the CTT track is different from the A-layer scintillator hit that confirms the wire hits. Again, though, both scintillator hits must occur in the same region and octant of the detector.

2.3.3 Signed Trigger

The CTT also sends a "sign" bit to the Level 1 Muon system, indicating whether the curvature of a track is positive or negative. The Level 1 Muon can then use this information to form a signed trigger – for instance, a trigger that fires only if a PT4 track with positive curvature is found. Both loose and tight signed triggers are formed. These triggers differ from the unsigned loose and tight triggers only in the requirement on the sign bit. These signed triggers are currently only used to form opposite-sign triggers at the global trigger level.

3 Regional Triggers

Regional triggers are formed by the Muon Trigger Card Manager (MTCM), which combines the octant-level trigger decisions from all eight octants of a region to form a regional trigger decision. The MTCM forms dimuon triggers by summing the octant-level triggers from the individual octants. Thus, if there is a single muon tight scintillator trigger fired in two different octants, the MTCM will form a regional dimuon tight scintillator trigger. (The regional single muon tight scintillator trigger will also fire.) The regional dimuon trigger will also fire if there is a dimuon trigger in any single octant. The regional triggers also form the so-called "combination" triggers, combining CTT and wire triggers within an octant with wire triggers formed within the same octant.

4 Global Triggers

Global triggers are formed by the Muon Trigger Manager (MTM), which takes as its inputs the regional trigger decisions of the MTCMs. Just as the MTCMs combine octant-level triggers to make a trigger for an entire region, the MTM combines regional triggers into a trigger decision for the entire muon detector. Single muon tight scintillator triggers fired in two different regions will thus be combined to fire a global dimuon tight scintillator trigger (as well as firing a global single muon tight scintillator trigger).

It should be noted that the MTM can specify that a trigger comes from a certain region of the detector. Thus, MTM terms may demand that a trigger comes from a single region (as is the case for the trigger term *mu2ptxclxx*, which requires a loose dimuon scintillator trigger from the central region), two regions (as with *mu1ptxbtxx*, which requires a tight scintillator trigger in either the north or south region), or parts of all three regions (as with *mu1ptxwtxx*, which requires a tight scintillator trigger in either the central region or in the "wide" region of either the north or the south). The "all" trigger (as in *mu1ptxatxx*) requires a trigger in either the north, south, or central region.

4.1 Opposite-Sign Trigger

The MTM forms opposite-sign dimuon triggers by counting the number and type of signed triggers formed in each region of the detector. If at least one positive-sign trigger and one negative-sign trigger above a given transverse momentum threshold fire, then the global opposite-sign trigger fires. Thus, if a loose, positive-sign, PT1 trigger fires in octant 4 of the central region and a loose, negative-sign, PT2 trigger fires in octant 2 of the central region, then the global trigger (*mu2pt1clxo*), corresponding to a loose opposite-sign dimuon trigger in the central region, will also fire. (Remember that if PT2 trigger fires in an octant, then the PT1 trigger in that octant fires as well.)

Because the MTM only receives information as to whether or not a signed trigger fired, it cannot decode which scintillator recorded the hit that allowed the trigger to fire. Thus, it is possible for an opposite-sign dimuon track to fire even if only one scintillator is hit, provided that both a positive-sign track and negative-sign track point to the same scintillator. This can happen often if multiple tracks are constructed for a high-momentum (and thus low-curvature) muon.

5 Rates, Efficiencies, and Purities

Rates for the new triggers were measured for a special run (run number 190346) with initial luminosity of 45E30 cm-2 sec-1. In the central region, the tight scintillator-only (*mu1ptxctxx*) trigger fired at 2848 Hz, the tight scintillator-loose wire (*mu1ptxctlx*) trigger fired at 523 Hz, and the tight scintillator-tight wire (*mu1ptxcttx*) trigger fired at 286 Hz. The efficiency of the *mu1ptxcttx* trigger relative to the *mu1ptxctlx* trigger was found to be 99%, where efficiency was defined as

$$\frac{\text{events with a reconstructed nseg=3 muon in which } \textit{mu1ptxcttx} \text{ trigger fired}}{\text{events with a reconstructed nseg=3 muon in which } \textit{mu1ptxctlx} \text{ trigger fired}}.$$

Of the 1% of events in which the *mu1ptxctlx* trigger fired but the *mu1ptxcttx* trigger did not, 3/4 were found to be events in which there were insufficient PDT hits in a single layer to cause the mu1ptxcttx trigger to fire. The remaining events had PDT hits outside the allowed roads of the trigger.

In the forward region, the tight scintillator-only (*mu1ptxbtxx*) trigger fired at 1886 Hz, the tight scintillator-loose wire (*mu1ptxbtlx*) trigger fired at 387 Hz, and the tight scintillator-tight wire (*mu1ptxbttx*) trigger fired at 353 Hz. The efficiency of the *mu1ptxbttx* trigger relative to the *mu1ptxbtlx* trigger was found to be 95%, where efficiency was defined in the same manner as for the central trigger. Of the events which fired the *mu1ptxbtlx* trigger but did not fire the *mu1ptxbttx* trigger, roughly half were found to be outside the acceptance of the B- and C-layer MDTs. The remaining events had MDT hits that were outside the Level 1 trigger roads.

The purity of the tight scintillator-tight wire trigger versus octant is shown in Figure 5. The purity in the central region was found to be 72.3±0.5%, and the purity in the forward region was found to be 83.2±0.4%.

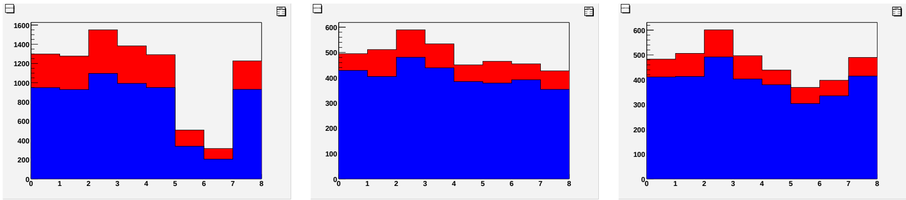

Figure 5: Purity of the tight scintilllator-tight wire triggers versus octant for triggers in the (a) central, (b) north, and (c) south region of the detector. The red histograms represent events in which the tight scintillator-tight wire trigger fired, and the blue histograms represent events in which the trigger fired and an nseg=3 muon was found.

A Appendix 1: Differences from Previous Versions

The following changes have been made between this version of the Level 1 Muon logic and previous versions (i.e., versions running prior to June 29, 2004):

1. loose scintillator triggers – These have been changed from "A-layer" hits to "A-layer or B-layer or C-layer" hits in central octants 5 and 6. They remain "A-layer" hits everywhere else.

2. tight scintillator triggers – The tight scintillator roads in bottom octants 5 and 6 have been tightened compared to previous versions. This change reduced rates from the bottom octants, with a negligible decrease in efficiency.

3. loose wire triggers – As with the loose scintillator triggers, the definition of a loose wire trigger in central octants 5 and 6 has been changed from "A-layer" to "A-layer or B-layer or C-layer"

4. tight wire triggers – These are new triggers, not available in previous versions of the Level 1 Muon trigger.

5. loose CTT triggers – CTT tracks may be confirmed with either an A-layer, B-layer or C-layer scintilator hit in central octants 5 or 6. Previous versions required an A-layer hit in these octants.

6. tight CTT triggers – CTT tracks are now confirmed by A-layer pixels, and a tight A-layer + B-layer pixel road is required. (In previous versions, tracks were confirmed by B-layer pixels, and either AB or BC pixel roads were required.)

7. wide triggers – The η-range of the "wide" trigger has been expanded, from $|\eta| < 1.5$ in previous versions to $|\eta| < 1.6$ in the new version. The new η-range fully encompasses the CFT.

Table 1 shows which of these changes affect each Level 1 Muon trigger term.

Trigger	Change from previous version
mu1ptxctxx	2
mu1ptxwtxx	2,7
mu1ptxatxx	2
mu1ptxbtxx	2
mu1ptxclxa	1
mu1ptxctlx	2,3
mu1ptxwtlx	2,3,7
mu1ptxatlx	2,3
mu1ptxwttx	2,4
mu1ptxattx	2,4
mu2ptxctxx	2
mu2ptxwtxx	2,7
mu2ptxatxx	2
mu2ptxbtxx	2
mu2ptxctxl	1,2
mu2ptxclxx	1
mu2ptxalxx	1
mu2ptxallx	1,3
mu2ptxcllx	1,3
mu2pt1clxx	1,5
mu2pt1cllx	1,3,5
mu1pt1wllx	1,3,5,7
mu1pt2wtlx	2,3,6,7
mu1pt3wtlx	2,3,6,7
mu1pt3wllx	1,3,5,7
mu1pt4wlxx	1,5,7
mu2pt4wlxx	1,5,7
mu1pt4wllx	1,3,5,7

Table 1: Changes to Level 1 Muon triggers in new version of trigger logic

B Appendix 2: Differences from Previous Versions

Up to 32 Level 1 Muon triggers can be sent to the trigger framework. These triggers appear on And/Or terms 80-95 and terms 192-207. Tabel 2 provides a list of those triggers provided to the framework for the v12 and v13 trigger lists. It should be noted that not all terms provided in the v12 list were used by the trigger framework, which is why the list of v13 And/Or terms is shorter than the list of v12 terms.

And/Or Term	v12 Trigger	v13 Trigger	And/Or Term	v12 Trigger	v13 Trigger
80	mu1ptxctxx	mu1ptxctxx	192	mu1ptxctlx	mu1ptxwtlx
81	mu1ptxbtxx	mu1ptxbtxx	193	OR of BOTs[1]	OR of BOTs[1]
82	mu2ptxbtxx	mu1pt1cllx	194	AND of BOTs[1]	AND of BOTs[1]
83	mu2ptxctxx	mu1pt1wllx	195	mu1pt4wlxx	mu1ptxwttx
84	mu1ptxwtxx	mu1pt2wtlx	196	mu2pt4wlxx	mu1ptxwtxx
85	mu1ptxatxx	mu1pt2wttx	197	mu1pt4wllx	mu2pt1cllo
86	mu2ptxwtxx	mu1pt3wtlx	198	mu1pt4wtxx	mu2pt1cllx
87	mu2ptxatxx	mu1pt3wtxx	199	mu1pt3wtlx	mu2ptxallx
88	mu1ptxclxx	mu1pt4wllx	200	mu2pt1cllx	mu2ptxatxx
89	mu2ptxctxl	mu1pt4wlxx	201	mu1pt2wtlx	mu2ptxcllx
90	mu2ptxclxx	mu1pt4wtxx	202	mu1ptxwttx[2]	mu2ptxwllx
91	mu1ptxwtlx	mu1ptxatlx	203	mu1ptxattx[2]	-
92	mu2ptxalxx	mu1ptxatxx	204	mu1pt3wllx	-
93	mu1ptxatlx	mu1ptxbttx	205	mu2ptxallx	-
94	mu2pt1clxx	mu1ptxclxa	206	mu1pt1wllx	-
95	mu2ptxcllx	mu1ptxctlx	207	mu1pt3wtxx	-

Table 2: Level 1 Muon And/Or terms in v12 and v13 trigger lists

[1] 'BOT' is a Beginning-Of-Turn synchronization trigger that fires once per turn. It is used for monitoring purposes.

[2] Although tight wire triggers were assigned to And/Or terms in v12, the logic forming these triggers was nonsensical, and these triggers were not used in any physics trigger list.